CHAPTER 9
FABRIC FILTERS

9-1. Fabric filtration

Fabric filters are used to remove particles from a gas stream. Fabric filters are made of a woven or felted material in the shape of a cylindrical bag or a flat supported envelope. These elements are contained in a housing which has gas inlet and outlet connections, a dust collection hopper; and a cleaning mechanism for periodic removal of the collected dust from the fabric. In operation, dust laden gas flows through the filters, which remove the particles from the gas stream. A typical fabric filter system (baghouse) is illustrated in figure 9-1.

9-2. Types of filtering systems

The mechanisms of fabric filtration are identical regardless of variations in equipment structure and design. In all cases, particulates are filtered from the gas stream as the gas passes through a deposited dust matrix, supported on a fabric media. The dust is removed from the fabric periodically by one of the available cleaning methods. This basic process may be carried out by many different types of fabric filters with a variety of equipment designs. Filtering systems are differentiated by housing design, filter arrangement, and filter cleaning method.

a. Housing design. There are two basic housing configurations which apply to boiler and incinerator flue gas cleaning. These are closed pressure, and closed suction.

(1) The closed pressure baghouse is a completely closed unit having the fan located on the dirty side of the system. Toxic gases and gases with high dew points are handled in this type of baghouse. Fan maintenance problems arise due to the fact that the fan is in the dirty gas stream before the baghouse. The floor of the unit is closed and the hoppers are insulated. A closed pressure baghouse is illustrated in figure 9-2.

(2) The closed suction is the most expensive type of baghouse, with the fan being located on the clean gas side. The closed suction baghouse is an all-welded, air-tight structure. The floor is closed, and the walls and hopper are insulated. Fan maintenance is less than with the pressure type, but inspection of bags is more difficult. A closed suction system is illustrated in figure 9-2.

b. Filter shape and arrangements.

(1) The cylindrical filter is the most common filter shape used in fabric filtration. The principal advantage of a cylindrical filter is that it can be made very long. This maximizes total cloth area per square foot of floor space. Cylindrical filters are arranged to accommodate each of the basic flow configurations shown in figure 9-3.

(2) A panel type filter consists of flat areas of cloth stretched over an adjustable frame. (See figure 9-3.) Flow directions are usually horizontal. Panel filters allow 20 to 40 percent more cloth per cubic foot of collector volume and panels may be brushed down if dust build-up occurs. However, panel-type filters are not widely used in boiler and incinerator applications.

c. Cleaning methods. A fabric cleaning mechanism must impart enough energy to the cloth to overcome particle adhering forces without damaging the cloth, disturbing particle deposits in the hopper; or removing too much of the residual dust deposit on the filter. The cleaning period should be much shorter than the filtering period. The correct choice of cleaning method for a particular application will greatly enhance the performance of the fabric filter system. An incorrectly matched cleaning method can result in high pressure drops, low collection efficiency, or decreased bag life. A performance comparison of the various cleaning methods is given in table 9-1.

(1) *Mechanical shake.* Some baghouses employ a type of mechanical shaking mechanism for cleaning. Bags are usually shaken from the upper fastenings, producing vertical, horizontal, or a combination of motions, on the bag. All bags in a compartment may be fastened to a common framework, or rows of bags are attached to a common rocking shaft. After the bags have been shaken, loosened dust is allowed to settle before filtration is resumed. The entire cleaning cycle may take from 30 seconds to a few minutes. Some designs incorporate a slight reversal of gas flow to aid in dust cake removal and settling, as any

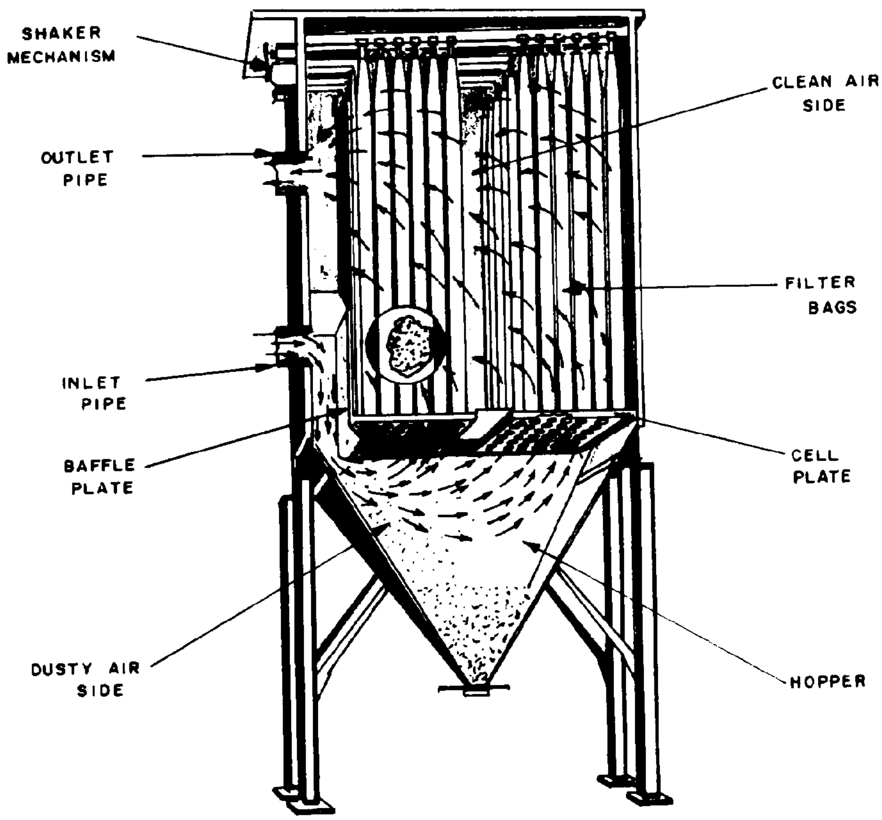

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Figure 9–1. Typical baghouse (shake clean)

slight flow in the direction of normal filtration will greatly reduce the effectiveness of cleaning. For this reason a positive sealing type valve is recommended for baghouse inlet and outlet. Shaker baghouses are normally used in small capacity systems or systems with a large number of filtering compartments.

(2) *Reverse flow without bag collapse.* This cleaning method is used with a dust that releases fairly easily from the fabric. (See figure 9-4). A low pressure reversal of flow is all that is necessary to remove deposited dust from fabric. To minimize flexure and wear; the fabric is supported by a metal grid, mesh, or rings, sewn into the bag. Any flow that is reversed through the filter must refiltered. This results in increased total flow, requiring a greater cloth area, and producing a higher filtering velocity. This net increase in flow is normally less than 10 percent. Reverse pressures range from 125 pounds/square inch (lb/in^2) down to a few inches, water gauge. The gentle cleaning action of reverse flow allows the use of glass fabric bags in high-temperature applications.

(3) *Reverse flow with bag collapse.* Even though flexure can be detrimental to the bag, it is frequently utilized in order to increase the effectiveness of cleaning in a reverse baghouse. Filter bags collecting dust on the inside of the fabric are collapsed by a burst of reverse air which snaps the dust cake from the cloth surface. The bags do not collapse completely but form a cloverleaf type pattern. Collapse cleaning uses the same equipment arrangement as reverse flow without bag collapse. One design sends a short pulse of air down the inside of the bag, along with the reverse flow, to produce increased flexure and cleaning as is illustrated in figure 9-5. The principal disadvantage of flexural cleaning is the increased fabric wear. If the dust cake fails to be removed completely, the bag will stiffen in that area and cause wear in adjacent areas during cleaning.

(4) *Reverse-flow heating.* With a reverse flow cleaning system it may be necessary to have a reverse flow heating system. This system

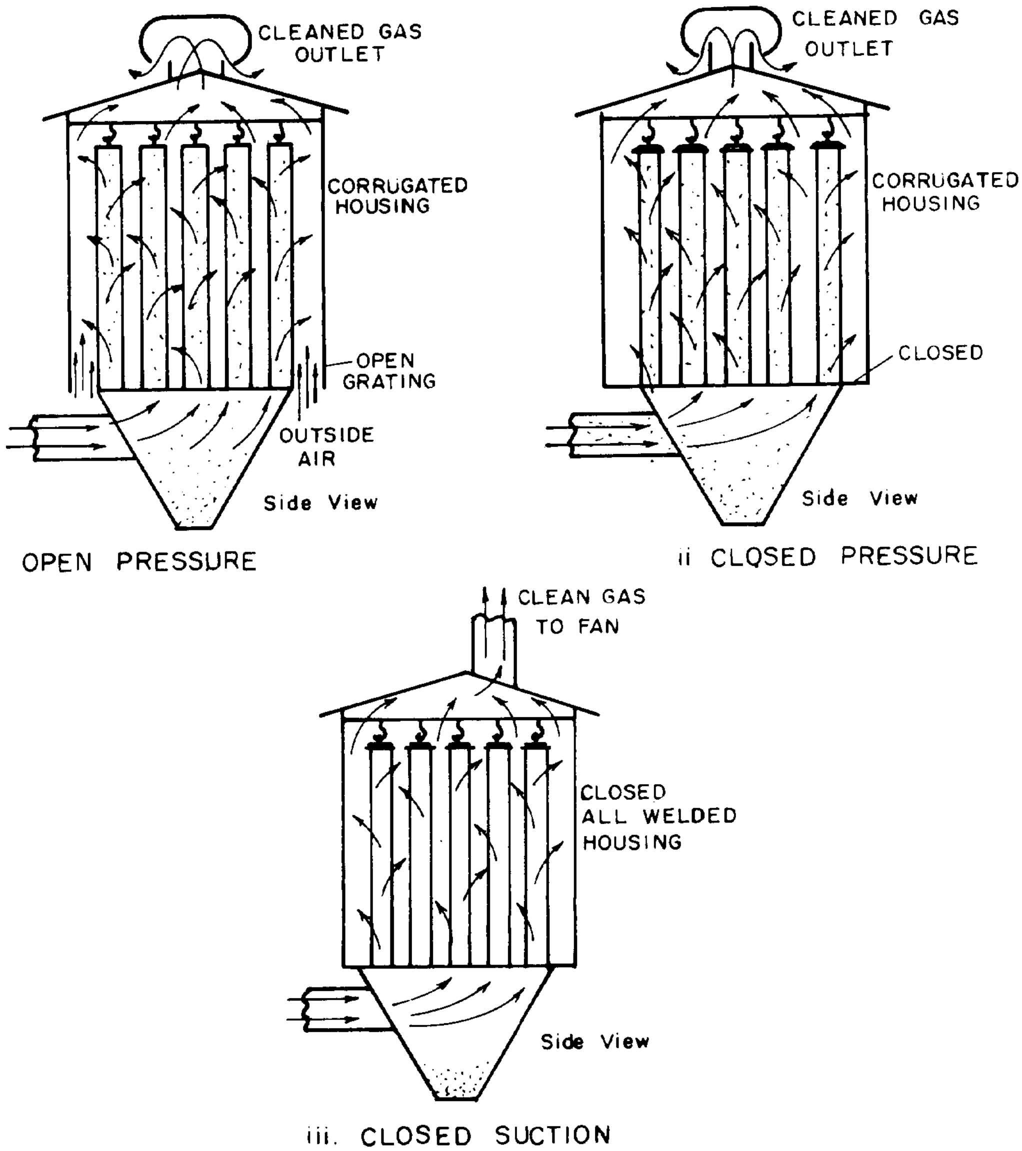

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Figure 9–2. Fabric filter housing design

would be used to keep the gas temperatures in the baghouse above the acid dew point during the cleaning cycle.

(5) *Pulse-jet.* A pulse jet system is illustrated in figure 9-6. A short blast of air at 29 to 100 lb/ in_2 is directed into the top of the filter. This blast is usually sent through a venturi which increases the shock effect. As the pulse starts down the filter tube, more air is drawn in through the top. This combination causes the flow within the bag to temporarily reverse, bulges the fabric, and releases the dust cake from the outside of the filter tube. The whole process occurs in a fraction of a second which enables a virtually continuous filtering flow. Filter elements can be pulsed individually, or in rows. With a multicompartment baghouse, a whole section may be pulsed at one time through a single venturi. The pulse produces less fabric motion than in shaking and also allows tighter bag spacing. A pulse-jet cleaning system requires no moving parts for cleaning and is designed to handle high gas flows per square foot of cloth area (air to cloth ratio). However; this system requires a compressed air system with a timer mechanism and control air solenoid valve for automatic cyclic cleaning. Pulse-jet

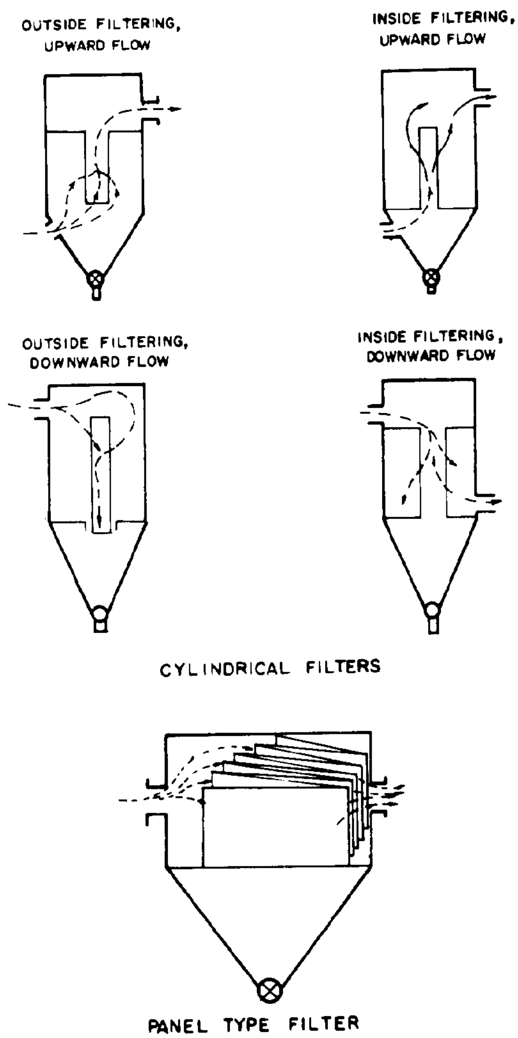

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Figure 9-3. Filter shape and arrangement

baghouses are used when dust concentrations are high and continuous filtering is needed.

9-3. Fabric characteristics and selection

Fabric filter performance depends greatly upon the correct selection of a fabric. A fabric must be able to efficiently collect a specific dust, be compatible with the gas medium flowing through it, and be able to release the dust easily when cleaned. Fiber, yarn structure, and other fabric parameters will affect fabric performance. At the present time, the prediction of fabric pressure drop, collection efficiency, and fabric life is determined from past performance. It is generally accepted practice to rely on the experience of the manufacturer in selecting a fabric for a specific condition. However, the important fabric parameters are defined below to aid the user in understanding the significance of the fabric media in filtration.

a. Fabric type. The two basic types of fabric used in filtration are woven and felted. The woven fabric acts as a support on which a layer of dust is collected which forms a microporous layer and removes particles from the gas stream efficiently. A felted material consists of a matrix of closely spaced fibers which collect particles within its structure, and also utilizes the filter cake for further sieving. Filtering velocities for woven fabrics are generally lower than felts because of the necessity of rebuilding the cake media after each cleaning cycle. It is necessary that woven fabrics not be overcleaned, as this will eliminate the residual dust accumulation that insures rapid formation of the filter cake and high collection efficiencies. Felts operate with less filter cake. This necessitates more frequent cleaning with a higher cleaning energy applied. Woven products, usually more flexible than felts, may be shaken or flexed for cleaning. Felts are usually back-washed with higher pressure differential air and are mainly used in pulse-jet baghouses. However, felted bags do not function well in the collection of fines because the very fine particles become embedded in the felt and are difficult to remove in the cleaning cycle.

b. Fiber. The basic structural unit of cloth is the single fiber. Fiber must be selected to operate satisfactorily in the temperature and chemical environment of the gas being cleaned. Fiber strength and abrasion resistance are also necessary for extended filter life. The first materials used in fabric collectors were natural fibers such as cotton and wool. Those fibers have limited maximum operating temperatures (approximately 200 degrees Fahrenheit) and are susceptible to degradation from abrasion and acid condensation. Although natural fibers are still used for many applications, synthetic fibers such as acrylics, nylons, and Teflon have been increasingly applied because of their superior resistance to high temperatures and chemical attack (table 9-2).

(1) Acrylics offer a good combination of abrasion resistance and resistance to heat degradation under both wet and dry conditions. An outstanding characteristic of acrylics is the ability to withstand a hot acid environment, making them a good choice in the filtration of high sulfur-content exhaust gases.

(2) An outstanding nylon fiber available for fabric filters is Nomen, a proprietary fiber developed by Dupont for applications requiring good dimensional stability and heat resistance. Nomen nylon does not melt, but degrades rapidly in temperatures above 700 degrees Fahrenheit. Its effective operating limit is 450 degrees Fahrenheit. When in contact with steam or with small amounts of water vapor at elevated temperatures, Nomen exhibits a progressive loss of strength. However, it withstands these conditions better

TABLE 9-1

PERFORMANCE COMPARISON OF FABRIC FILTER CLEANING METHODS

System Type	Pressure Loss (in. of water)	Efficiency	Typical Cloth Type	Filter (cfm/ft^2 Cloth area)	Recommended Application	Advantages	Disadvantages
Shaker	3-6	99+%	Woven	1-5	Dust with good filter cleaning properties, intermittent collection	Relatively low initial investment	Bag failure increases with intensity and frequency of cleaning. Not suitable for fragile fabric and sticky dusts.
Reverse Flow	3-6	99+%	Woven	1-5	Dust with good filter cleaning properties, high temperature collection (incinerator fly ash) with glass bags	Low cloth attrition	Requires extra cloth capacity, additional fan and dampers.
Pulse Jet	3-6	99+%	Felted	5-20	Efficient for coal and oil fly ash collection.	Continuous flow pattern, low cloth attrition, unlimited dust concentration capability, no moving parts, no need for ducting dampers.	Compressed air required, high equipment cost.

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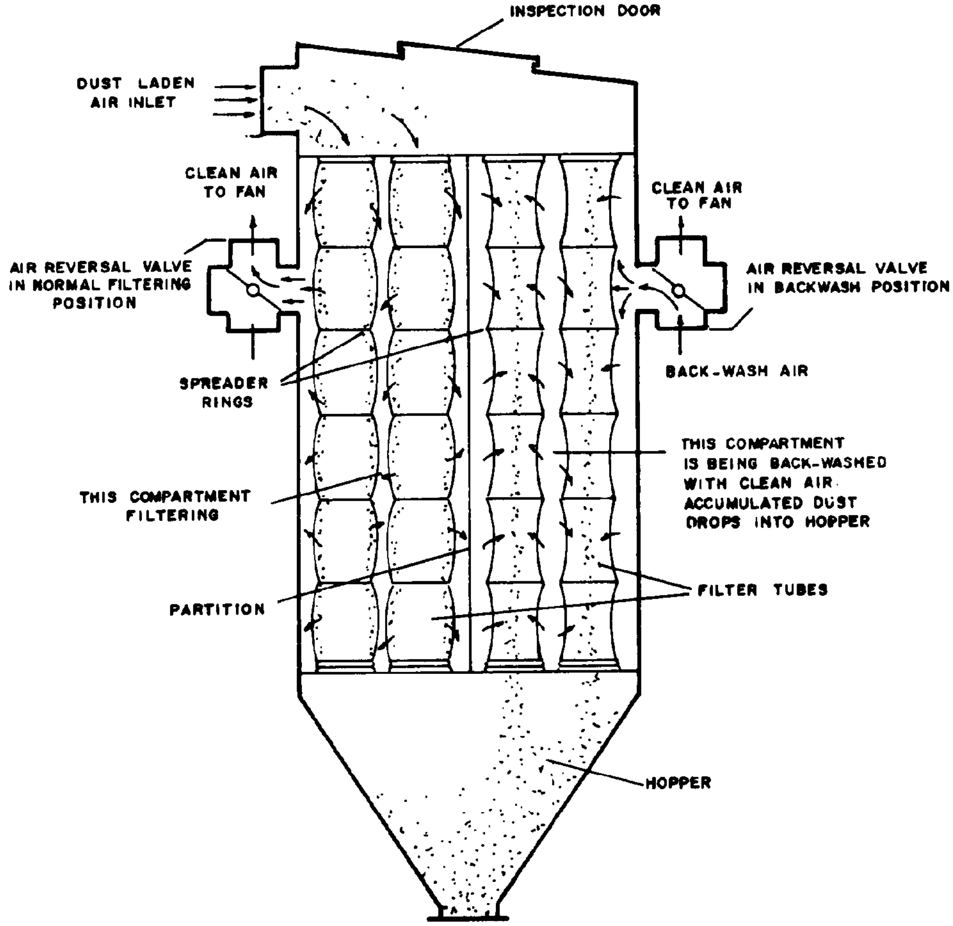

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Figure 9-4. Reverse flow baghouse (without bag collapse)

than other nylons and many other fibers. Because of Nomen's high abrasion resistance, it is used in filtration of abrasive dusts or wet abrasive solids and its good elasticity makes it ideal for applications where continuous flexing takes place. All nylon fabrics provide good cake discharge for work with sticky dusts.

(3) Teflon is the most chemically resistant fiber produced. The only substances known to react with this fiber are molten alkali metals, fluorine gas at high temperature and pressure, and carbon trifluoride. Teflon fibers have a very low coefficient of friction which produces excellent cake discharge properties. This fact, coupled with its chemical inertness and resistance to dry and moist heat degradation, make Teflon suitable for filtration and dust collection under severe conditions. Its major disadvantages are its poor abrasion resistance and high price. For these reasons, Teflon would be an economical choice only in an application where extreme conditions will shorten the service life of other filter fibers. It should be noted that the toxic gases produced by the decomposition of Teflon at high temperatures can pose a health hazard to personnel and they must be removed from the work area through ventilation.

c. Yarn type. Performance characteristics of filter cloth depend not only on fiber material, but also on the way the fibers are put together in forming the yarn. Yarns are generally classified as staple (spun) or filament.

(1) Filament yarns show better release characteristics for certain dusts and fumes, especially with less vigorous cleaning methods.

(2) Staple yarn generally produces a fabric of greater thickness and weight with high permeability to air flow. Certain fumes or dusts

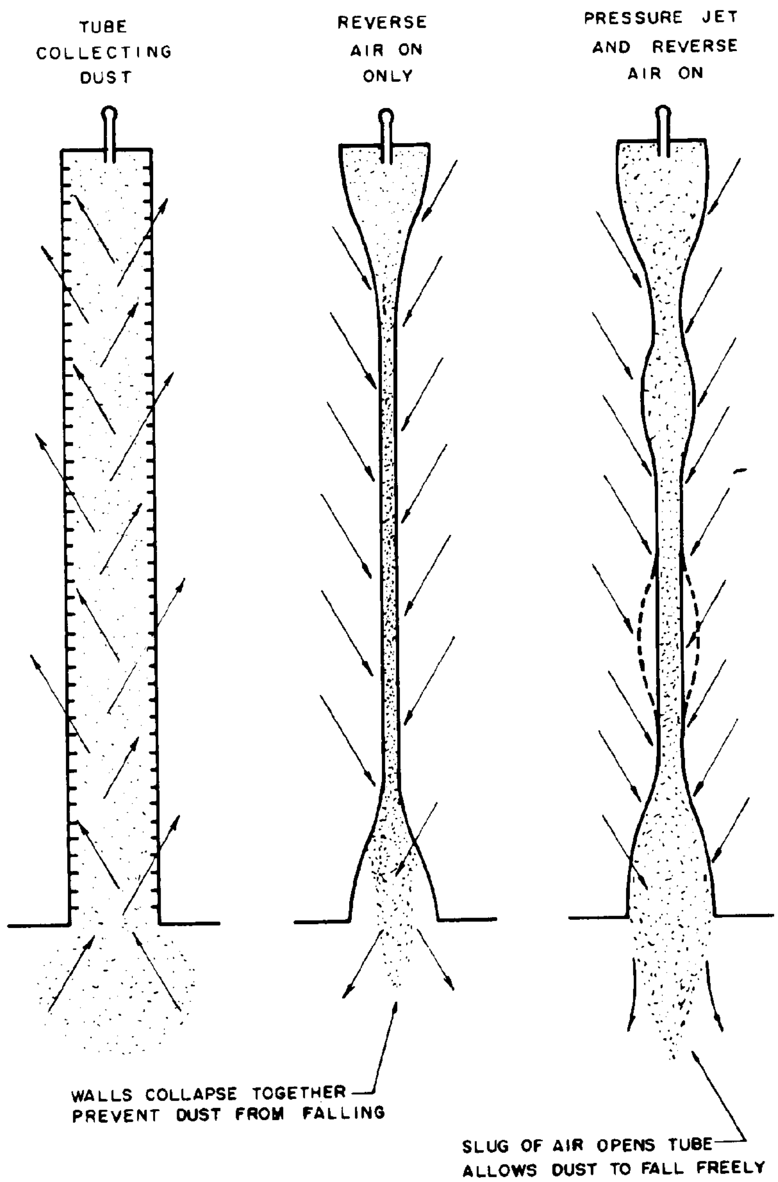

Figure 9–5. Reverse flow cleaning (with bag collapse)

undergoing a change of state may condense on fiber ends and become harder to remove from the fabric.

d. Weave. The weave of a fabric is an important characteristic which affects filtration performance. The three basic weaves are plain, twill, and satin.

(1) Plain weave is the simplest and least expensive method of fabric construction. It has a high thread count, is firm, and wears well.

(2) Twill weave gives the fabric greater porosity, greater pliability, and resilience. For this reason, twill weaves are commonly used where strong construction is essential.

(3) Satin fabrics drape very well because the fabric weight is heavier than in other weaves. The yarns are compacted which produces fabric body and lower porosity, and they are often used in baghouses operating at ambient temperatures.

e. Finish. Finishes are often applied to fabrics to lengthen fabric life. Cotton and wool can be treated to provide waterproofing, mothproofing, mildewproofing, and fireproofing. Synthetic fabrics can be heat-set to minimize internal stresses and enhance dimensional stability. Water repellents and antistatic agents may also be applied. Glass fabrics are lubricated with silicon or graphite to reduce the internal abrasion from

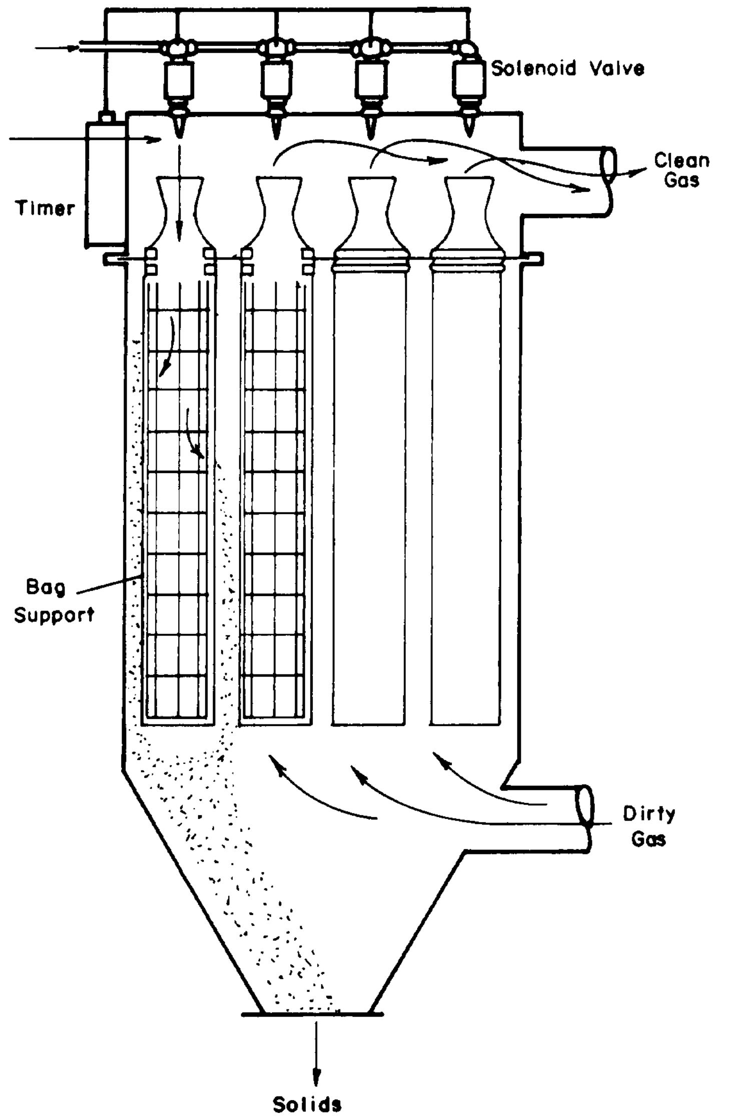

Figure 9–6. Pulse-jet baghouse

brittle yarns. This has been found to greatly increase bag life in high temperature operations.

f. Weight. Fabric weight is dependent upon the density of construction, and fiber or yarn weight. Heavier fabric construction yields lower permeability and increased strength.

9-4. Materials and construction

a. Collector housing. Small unit collectors can be assembled at the factory or on location. Multicompartment assemblies can be shipped by compartment or module (group of compartments), and assembled on-site. Field assembly is disadvantageous because of the need for insuring a good seal between panels, modules and flanges. Baghouse collector wall and ceiling panels are constructed of aluminum, corrugated steel, or concrete, the limitations being pressure, temperature, and corrosiveness of the effluent. The metal thickness must be adequate to withstand the pressure or vacuum within the baghouse and sufficient bracing should be provided. If insulation is needed, it can be placed between wall panels of adjacent compartments and applied to the outside of the structure. Pressure-relieving doors or panels should be included in the housing or ductwork to protect equipment if any explosive dust is being handled. An easy access to the baghouse interior must be provided for maintenance. Compartmented units have the advantage of being able to remain on-line while one section is out for maintenance. Walkways should be provided for access to all portions of the cleaning mechanism. Units with

TABLE 9-2

PROPERTIES OF FIBERS FOR HIGH TEMPERATURE DRY FILTRATION

Fiber: Generic Name / Trade Name	Aramid Nomex	Glass Fiberglas	PTFE Teflon	Polyphenylene Sulfide Ryton	Polybenzi-Midazole PBI	Metal Bekinox	Ceramic Nextel 312
Recommended continuous operation temperature (dry heat)	400°F	500°F	500°F	385°F	500°F	850°F	2,100°F
Water vapor saturated condition (moist heat)	350°F	500°F	500°F	375°F	500°F	750°F	2,199°F
Maximum (short time) operation temperature (dry heat)	450°F	550°F	550°F	450°F	650°F	950°F	2,600°F
Specific density	1.38	2.54	2.3	1.38	1.43	7.9	2.7
Relative moisture regain in % (at 68°F and 65% relative moisture	4.5	0	0	0.6	14	0	0
Supports combustion	No	No	No	No	No	No	No
Biological resistance (bacteria, mildew)	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect
Resistance to alkalies	Good	Fair	lent	Excellent	Good	Good	Good
Resistance to mineral acids	Fair	Very Good	Excel-lent	Excellent	Excellent	Very Good	Very Good
Resistance to organic acids	Fair +	Very Good	Excel-lent	Excellent	Excellent	Very Good	Very Good
Resistance to oxidizing agents	Poor	Excel-lent	Excel-lent	attacked by strong oxidiz-ing agents.	Fair	Very Good	Excellent
Resistance to organic solvents	Very Good	Very Good	Excel-lent	Excellent	Excellent	Very Good	Excellent

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bags longer than 10 to 12 feet should be provided with walkways at the upper and lower bag attachment levels.

b. Hopper and disposal equipment. The dust-collection hopper of a baghouse can be constructed of the same material as the external housing. In small light duty, hoppers 16 gage metal is typical. However, metal wall thicknesses should be increased for larger baghouses and hopper dust weight. The walls of the hopper must be insulated and should have heaters if condensation might occur. The hopper sides should be sloped a minimum of 57 degrees to allow dust to flow freely. To prevent bridging of certain dusts, a greater hopper angle is needed, but continuous removal of the dust will also alleviate bridging. If dust bridging is a significant problem, vibrators or rappers may be installed on the outside of the hopper. The rapping mechanism can be electrically or pneumatically operated and the size of the hopper must be sufficient to hold the collected dust until it is removed. Overfilled hoppers may cause an increased dust load on the filter cloths and result in increased pressure drop across the collector assembly. Storage hoppers in baghouses which are under positive or negative pressure warrant the use of an air-lock valve for discharging dust. Since this will prevent re-entrainment of dust or dust blowout. A rotary air valve is best suited for this purpose.

c. For low solids flow, a manual device such as a slide gate, trip gate, or trickle valve may be used, however, sliding gates can only be operated when the compartment is shut down. For multicompartmented units, screw conveyors, air slides, belt conveyors or bucket conveying systems are practical. When a screw conveyor or rotary valve is used, a rapper can be operated by a cam from the same motor.

9-5. Auxiliary equipment and control systems

a. Instrumentation. Optimum performance of a fabric filter system depends upon continuous control of gas temperature, system pressure drop, fabric pressure, gas volume, humidity, condensation, and dust levels in hoppers. Continuous measurements of fabric pressure drop, regardless of the collector size, should be provided. Pressure gages are usually provided by the filter manufacturer. With high and with variable dust loadings, correct fabric pressure drop is critical for proper operation and maintenance. Simple draft gages may be used for measuring fabric pressure drop, and they will also give the static pressures at various points within the system. Observation of key pressures within small systems, permits manual adjustment of gas flows and actuation of the cleaning mechanisms.

b. The number and degree of sophistication of pressure-sensing devices is relative to the size and cost of the fabric filter system. High temperature filtration will require that the gas temperature not exceed the tolerance limits of the fabric and temperature displays are required to indicate whether necessary dilution air-dampers or pre-cooling sprays are operating correctly. A well-instrumented fabric filter system protects the investment and decreases chances of malfunctions. It also enables the operating user to diagnose and correct minor problems without outside aid.

c. Gas preconditioning. Cooling the inlet gas to a fabric filter reduce the gas volume which then reduces required cloth area; extends fabric life by lowering the filtering temperature; and permits less expensive and durable materials to be used. Gas cooling is mandatory when the effluent temperature is greater than the maximum operating temperature of available fabrics. Three practical methods of gas cooling are radiation convection cooling, evaporation, and dilution.

(1) Radiation convection cooling enables fluctuations in temperature, pressure, or flow to be dampened. Cooling is achieved by passing the gas through a duct or heat-transfer device and there is no increase in gas filtering volume. However, ducting costs, space requirements, and dust sedimentation are problems with this method.

(2) Evaporative cooling is achieved by injecting water into the gas stream ahead of the filtering system. This effectively reduces gas temperatures and allows close control of filtering temperatures. However, evaporation may account for partial dust removal and incomplete evaporation may cause wetting and chemical attack of the filter media. A visible stack plume may occur if gas temperatures are reduced near to or below the dew point.

(3) Dilution cooling is achieved by mixing the gas steam with outside air. This method is inexpensive but increases filtered gas volume requiring an increase in baghouse size. It is possible the outside air which is added may also require conditioning to control dust and moisture content from ambient conditions.

9-6. Energy requirements.

The primary energy requirement of baghouses is the power necessary to move gas through the filter. Resistance to gas flow arises from the pressure drop across the filter media and flow losses resulting from friction and turbulent effects. In small or moderately sized baghouses, energy required to drive the cleaning mechanism and dust disposal equipment is small, and may be considered negligible when compared with primary fan energy. If heating of reverse air is needed this will require additional energy.

9-7. Application

a. Incinerators. Baghouses have not been widely used with incinerators for the following reasons:

(1) Maximum operating temperatures for fabric filters have typically been in the range of 450

to 550 degrees Fahrenheit, which is below the flue gas temperature of most incinerator installations

(2) Collection of condensed tar materials (typically emitted from incinerators) could lead to fabric plugging, high pressure drops, and loss of cleaning efficiency

(3) Presence of chlorine and moisture in solid waste leads to the formation of hydrochloric acid in exhaust gases, which attacks fiberglass and most other filter media

(4) Metal supporting frames show distortion above 500 degrees Fahrenheit and chemical attack of the bags by iron and sulphur at temperatures greater than 400 degrees Fahrenheit contribute to early bag failure. Any fabric filtering systems designed for particulate control of incinerators should include:

— fiberglass bags with silica, graphite, or teflon lubrication; or nylon and, teflon fabric bags for high temperature operation, or stainless steel fabric bags,
— carefully controlled gas cooling to reduce high temperature fluctuations and keep the temperature above the acid dew point,
— proper baghouse insulation and positive sealing against outside air infiltration. Reverse air should be heated to prevent condensation.

b. Boilers. Electric utilities and industrial boilers primarily use electrostatic precipitators for air pollution control, but some installations have been shown to be successful with reverse air and pulse-jet baghouses. The primary problem encountered with baghouse applications is the presence of sulphur in the fuel which leads to the formation of acids from sulphur dioxide (SO_2) and sulphur trioxide (SO_3) in the exhaust gases. Injection of alkaline additives (such as dolomite and limestone) upstream of baghouse inlets can reduce SO_2 present in the exhaust. Fabric filtering systems designed for particulate collection from boilers should:

— operate at temperatures above the acid dew point,
— employ a heated reverse air cleaning method,
— be constructed of corrosion resistant material,
— be insulated and employ internal heaters to prevent acid condensation when the installation is off-line.

c. SO_2 removal. The baghouse makes a good control device downstream of a spray dryer used for SO_2 removal and can remove additional SO_2 due to the passage of the flue-gas through unreacted lime collected on the bags.

d. Wood refuse boiler applications. It is not recommended that a baghouse be installed as a particulate collection device after a wood fired boiler. The possibility of a fire caused by the carry over of hot glowing particles is to great.

9-8. Performance

Significant testing has shown that emissions from a fabric filter consist of particles less than 1 micron in diameter. Overall fabric filter collection efficiency is 99 percent or greater (on a weight basis). The optimum operating characteristics attainable with proper design of fabric filter systems are shown in table 9-3.

9-9. Advantages and disadvantages

a. Advantages.

(1) Very high collection efficiencies possible (99.9 + percent) with a wide range of inlet grain loadings and particle size variations. Within certain limits fabric collectors have a constancy of static pressure and efficiency, for a wider range of particle sizes and concentrations than any other type of single dust collector.

(2) Collection efficiency not affected by sulfur content of the combustion fuel as in ESPs.

(3) Reduced sensitivity to particle size distribution.

(4) No high voltage requirements.

(5) Flammable dust may be collected.

(6) Use of special fibers or filter aids enables submicron removal of smoke and fumes.

(7) Collectors available in a wide range of configurations, sizes, and inlet and outlet locations.

b. Disadvantages.

(1) Fabric life may be substantially shortened in the presence of high acid or alkaline atmospheres, especially at elevated temperatures.

(2) Maximum operating temperature is limited to 550 degrees Fahrenheit, unless special fabrics are used.

(3) Collection of hygroscopic materials or condensation of moisture can lead to fabric plugging, loss of cleaning efficiency, large pressure losses.

(4) Certain dusts may require special fabric treatments to aid in reducing leakage or to assist in cake removal.

(5) High concentrations of dust present an explosion hazard.

(6) Fabric bags tend to burn or melt readily at temperature extremes.

TABLE 9-3

OPERATING CHARACTERISTICS OF FABRIC FILTERS

Collection efficiency	99 percent+
Particle size collected	Greater than .5 microns
Pressure drop	.5-6 inches, water gauge
Maximum operating temperatures	550 degrees Fahrenheit peak and 500 degrees Fahrenheit continuous with common fabrics
Dust concentration handled in particulate collection	0-10 gr/ft^3
Gas volume	Unlimited
Cloth area	Several square feet to several thousand square feet
Filtering velocities	1-15 ft/min
Average bag life	18 months to 2 years

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